THE INFLUENCE OF CLIMATE UPON HUMAN SOCIAL AND CULTURAL DEVELOPMENT IN PALESTINE DURING THE LAST GLACIATION

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INTRODUCTION

The geographical position of Palestine has made it one of the world's most important centers of human migration and racial mixture. Situated on the eastern coast of the Mediterranean Sea, it has undoubtedly served not only as a battlefield during prehistoric times, but also as a center for commerce during periods of peace and tranquility. Research reveals the fact that these intervals of peace and conflict have occurred in both prehistoric and historic times.

Human migration is due to a number of causes. Whatever the cause may be, any migrating group imposes to some extent its cultural pattern upon the population of the area in which it moves and, conversely, has the cultural pattern of the native population imposed upon it.

It is a common eventuality for a migrating group to fail to return to its original place of abode. Some migrating groups, however, will in time return when the cause which forced them to leave ceases to exist or is no longer detrimental to the existence and progress of human life. This has been especially true in the history of Palestine which has on many occasions been invaded by the Egyptians from Africa, the Mesopotamians from between the Euphrates and the Tigris, and other nations from Asia Minor. Such large scale invasions and intermingling as mentioned above must have resulted in some exchange of ideas and modifi-

cations of cultures among the peoples who took part in them.

The purpose of this investigation is to show, in a general way, what the varying condition of climate was in the Palestinian Area during the Last Glaciation, that is to say during a period from about 115,000 years ago up to approximately 20,000 years ago and also to show how climatic changes to some degree influenced the behavior of the people.

The Last Glaciation is roughly divided into five climatic phases, three maxima and two minima. A maximum phase is a period of glaciation in which the ice condition has reached its highest level of development. A minimum phase is a period of glaciation in which the ice condition has been reduced to a minimum.

Climate is the product of many causes, of which one is the amount, great, moderate, or small, of glaciation. Generally, a maximum phase of glaciation exerts a favorable influence upon climate in Palestine; a minimum phase exerts an opposite kind of influence. This is true even though some of the most notable achievements in human cultural development were accomplished under unfavorable climatic conditions during the period under discussion.

The writer wishes to emphasize that the establishment of the condition of the climate in a period as remote as c.115,000 years ago can be accepted as only generally reliable. The method of establishing the condition consists of the evaluation of archaeological, paleontological, geological, and astronomical evidences, along with a general correlation of the four kinds

of evidence in order to give as complete a history of the condition of climate as possible.

The writer has tried to obtain enough knowledge to establish the validity of the study by the following processes:

1. The writer studied and made a general evaluation of the history of the archeological material uncovered in the most important cave sites that have been excavated in Palestine. From the types and numerical incidence of some of the tools and other artifacts discovered, a general knowledge of the activities of the inhabitants in their quest for food and shelter has been gained. Further, the relation of the archeological levels has been used as a part of the means to establish the periods during which these activities took place.
2. From these sites many faunal remains of animal species have been investigated and classified. By studying climatic conditions under which some present-day animals live, the writer has gained some information about the condition of climate at the time some of the present types of animals lived in the past.
3. The third step consists of the evaluation of sedimentary deposits which have been uncovered within the intermountain region, in the Jordan Valley and on the coastal plain. The geological determination of the conditions under which the top soil, sandstones, gravels, rocks and marine sediments were formed and deposited, and the various depths at which the materials were uncovered, facili-

tate a determination of climatic conditions during the period under discussion.

4. The fourth step is the application of the astronomical theory of climatic changes to the Palestinian area. The purpose of this step is to determine the degree of change in the amount of radiation the earth received from the sun. A general explanation of its functional aspect is given in the proper section.

5. The fifth step consists of a general correlation of the four steps above. It is from this step that the influence of climate is to be developed. Here it suffices to say that climate affects man's food, his mode of life and his health. A change in the condition of climate usually causes a change in the activities of the people.

CHAPTER I

THE ARCHEOLOGICAL SUCCESSION OF PALESTINIAN INDUSTRIES

The Description and Climatic Evaluation of Palestinian Industries

Formation of Layers

When a group of inhabitants is forced by climatic conditions to leave a place of abode, many articles of their cultural equipment are usually left behind. After a period of time, these articles become embedded in the soil and are covered by accumulated drifts of debris. Thus, being covered on both sides, these pieces of equipment have formed what is called a layer.

When at a later date natural conditions become more favorable, another group of inhabitants will occupy the same place, usually atop of the remains of the preceding group. When this new group is eventually faced by an unfavorable change in its environment, it will also depart and leave natural evidence of its type of social life. It is from a continuous repetition of this process that we get our levels or layers.

By examining the remains from these layers, the archeologist is able to deduce certain information that is peculiar to the inhabitants who occupied the sites. This information, in a general way, indicates the time the sites were occupied, types of activities in which the inhabitants were engaged, the probable conditions under which these activities were carried out,

and the type of tools that were used to carry on these activities.

Cave Sites

The principal sources of the available archeological evidence are the Mount Carmel caves which are located on the seaward side of the Palestinian Mountains. Most of these caves are confined to the Wady el Mughara region and all are a few feet above sea level. This information concerning the cave sites is based entirely upon the works of Miss D. A. E. Garrod, who has carried out several investigations of the area.[1]

The Mugharet el Wad.--The largest of these caves is the Mugharet el Wad. It is situated at the south of the Wady el Mughara and contains seven layers that have been alphabetically listed from A to G. Extensive excavations have been carried out at this site.[2]

The Et Tabun.--This cave site is situated a short distance to the southwest of the Mugharet el Wad. It lies in a semicircular bay of the same stretch of cliff, but at a higher altitude. It contains nine levels that have been listed from B to G, including four sublayers under layer E. These two caves are by far the largest of the lot and will serve as the basis of our archelogical investigation for the Palestinian area.

Mugharet es Skhul.--The smallest and least impressive of

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[1]D. A. E. Garrod and D. M. A. Bate, The Stone Age of Mount Carmel (London, 1937), I, 3-70.

[2]See fig. 1, p.15.

the prehistoric sites of the Wady el Mughara region is the Mugharet es Skhul. It is located a little way up the valley about one hundred meters to the east of the Mugharet el Wad. This site contains material that falls into the Levalloiso-Mousterian period, which corresponds to layers C and D in Tabun.

The Kebarah Site.--The Kebarah site is located about 21 kilometers south of Wady el Mughara. It is named after the cave in which it is located, el Kebarah. More will be said about it when we consider the nature and importance of the industry found there.

The Tell of Jericho.--The Tell of Jericho is located in the Jordan depression. The importance of the deposits discovered at this site will be discussed when they are compared with deposits found at other sites in the area.

The Tahunian Site.--This site, also found in the Jordan Valley, is named after the river near which it is located, Wady Tahuneh. The artifacts discovered there are provisionally labeled as belonging to the early Neolithic phase in Palestinian chronology.[1]

Two other sites which are to be discussed are those of el-Khiam, which is located in Southern Syria, and Wad Shukba in the Judean hills. In the main, these two are surface sites and did not yield an abundance of material.

The sequence of archeological material for the Last Glaciation begins with the last layer of Tabun (layer B) and ends with the deposits of Mugharet el Wad (layer B). The chronological se-

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[1]Ibid., p. 118.

quence is developed by describing the artifacts found in each layer, beginning with Tabun B, and Wad G, and continuing up to the discoveries at Jericho and the Tahunian sites.

Upper Levalloiso-Mousterian
Tabun B and Wad G

The prevailing industry in Palestine during the first phase of the Last Glaciation was in the upper part of the Levalloiso-Mousterian. Tools used in this industry were made in the flake tradition. Flake tools were preceded in Palestine by tools in the core tradition. The thing that distinguishes tools in the flake tradition from those in the core tradition is the technique by which they were made. In the flake tradition tools were made by extracting a small piece of material from a larger piece and shaping it, by flaking, into the form the tool was desired to take. No finishing touches, as shaping or flaking by percussion, were applied in the core tradition. Some of the tools made in the flake tradition were burins, blades, scrapers, and chisels. Many of these tools were used in both parts of the Levalloiso-Mousterian, but it was the Upper part in which the extracting technique reached its highest level of development. Small blades and scrapers with multiple cutting edges, which were made sharper by considerable retouch, were made in the Upper Levalloiso-Mousterian culture at a time when man depended mainly upon animals for his food supply. Tools in the flake tradition were used primarily for hunting and killing animals and wild game. The flake tradition lasted in

Palestine until the beginning of the first glacial minimum phase. At that time, it was replaced by the blade tradition.

Blade Tool Tradition

Tools in the blade tradition were distinguished from those in the flake tradition by the sharpening process. In the blade tradition, tools were sharpened from the base toward the cutting edge. In the flake tradition, they were sharpened by flaking from the edge toward the base. The idea in the blade culture was to make a cutting blade, not just a crude implement with a cutting edge.

Some of the tools made in the blade tradition were scrapers, spiked points, blades, some of which were curve-shaped, and a small collection of special points that were made of bone.

Aurignacian.--The Aurignacian is the first known industry in the blade tradition for Palestine. It lasted from the first glacial minimum to well into the second glacial maximum phase. The Chatelperronian is the first of the three parts into which the Aurignacian is divided.

Chatelperronian--Wad F.--Tools in this category are delicately formed blades that are highly polished, and numerous points with sharp cutting edges. The climate was hot and dry, but not without some rainfall at the time these tools were used. The animals were mostly of the type that roamed the fields. The Chatelperronian covered the first half of the first glacial minimum. At that time hunting was the principal

method of obtaining a supply of food.

Middle Aurignacian--Wad E and D.--The Middle Aurignacian succeeded the Chatelperronian and lasted well into the second glacial maximum period. The most common tools found in the two levels are scrapers, points, blades, and burins. Numerous spiky points, made on delicate blades, and seven other points made of bone, were found in level E. Tools in this classification were designed to make hunting practices more effective, since hunting was the method of acquiring food. The climate was dry during the early part of the Middle Aurignacian, but became more humid near the beginning of the second glacial maximum. The increase in precipitation at this time was the cause of a general increase in the amount of vegetation, including a limited quantity of forest. As a consequence of the change of the climate from a hot and arid to a more humid condition, the supply of animals became sufficient to meet the needs of the inhabitants.

Upper Aurignacian--Wad C.--The artifacts found in the Upper Aurignacian are of the same tool types found in the Middle Aurignacian in Wad D. Some of the points were made on curved blades and some on straight-faced blades. Steep scrapers are the largest collection of tools discovered in this layer. Some of them are also curve-shaped, though most of them are straight-faced.

This phase of the Aurignacian lasted only a very short time; it covered the latter part of the second glacial maximum period. A slight decline in precipitation at that time caused a decrease in the food supply.

Atlitian--Wad C.--The Atlitian has strong affinities with the Upper Aurignacian. Burins and steep scrapers are the most numerous of the tools discovered in this layer. The reappearance of a small number of Chatelperronian points is the outstanding thing about this collection. The Chatelperronian had not been seen since the early part of the first glacial minimum period. The reappearnce of the Chatelperronian in the early part of the second glacial minimum period indicates that these were people who were accustomed to living in a hot and arid type of climate. To survive under this condition they had to be good hunters. That they were good hunters is attested by the highly developed Chatelperronian points and blades which have been described. Tools in the blade tradition were used for hunting, carving, and reaping some form of usable vegetation.

Microlithic Industries

Tools made in these industries are smaller, have sharper points and blades, and are less cumbersome than those made in earlier indistries. It was also in the Microlithic industries that the development of a variety of new tools took place. These new tools indicate that the inhabitants at that stage developed new and more effective methods of acquiring an adequate supply of food. The development of these new methods was made necessary by the unfavorable influence of a hot and arid climate that prevailed in Palestine during the second glacial minimum and the third glacial maximum of the Last Glaciation.

Natufian--Wad B.--The Natufian was first found at Shukba,

which is located at Wady Natuf in Judea.[1] The Natufian industry reached a higher development than any of the other cultures discovered in the Wady el Mughara region.

The Natufian assemblage at Wad B contains spears, arrow heads, sickle blades, and picks. Among the bone implements found are several points, harpoons, and sickle hafts. The spear, which was used for throwing from a distance; the sickle, which was used for cutting some form of vegetation; the arrow, which could be used from a concealed position; and gorgets, which were used for fishing, are all innovations that distinguish Microlithic industries from earlier cultures. The intensified action that is indicated by the development of new and different tools was due to a prolonged period of unfavorable climatic influences.

Kebaran--Level B of Kebarah.--It is not certain whether the Kebarans came before or after the Natufians in the succession of Palestinian industries. The close similarity of Kebaran tools to those of the Natufians indicates that they might have coexisted for a time in Palestine. The long curved sickle blades, the barbed harpoons with points on the base, and sickle hafts that were made of bone, reveal the strong affinity of the Kebaran and Natufian industries. The Kebaran industry lasted only for a short period of time, only during the middle of the second glacial minimum period. The climate at that time was hot and dry, with most of the available precipitation

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[1] Ibid., p. 114.

being confined to the coastal area.

Tahunian.--The Tahunian was first known in Palestine from surface finds made at the location of the cave site (Wady Tahuneh). The implements found include sickles, a notched arrow, pottery vessels, and metal. The discovery of pottery at this time indicates that water was stored for domestic purposes. Subsequently, a sounding made at el-Khiam, whose contents are described by the excavator (Neuville), revealed the presence of Tahunian stratified above Natufian.[1] This industry includes a number of typical microliths, with flaked chisels and axes predominating among the larger implements. Neuville thinks that, because of the strong affinity between the Tahunian and Natufian industries, the Tahunian might have derived from the Natufian. There is not enough evidence available to establish such a relationship at this time.

Tell of Jericho.--The information concerning the contents and description of the site of Jericho is based upon the works of Joan Crowfoot.[2] Upon examination, she found one flint industry from level XVII up through level IX. Pottery was present only in IX and later levels (VIII, VII, VI, etc.). The industry found between levels XVII and IX was classified as Tahunian II by Miss Crowfoot. Of the many arrow heads discovered, two were of the notched variety. One of these corresponded with the arrow head found in Natufian, and with Neuville's Tahunian of el-Khiam.

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[1] Ibid., p. 118.

[2] Joan Crowfoot, "Notes on the Flint Implements of Jericho," Annals of Archeology and Anthropology (1937), pp. 35-50.

Joan Crowfoot states that the industry of Jericho had "very definite affinities" with the Tahunian of surface sites, but also differed in many respects.[1] The similarities between the two caused her to call Jericho's industry Tahunian; but she called it Tahunian II because she did not feel that Jericho represented the beginning of the Tahunian phase.[2]

Nevertheless, Jericho materials, as is true with the Natufian and both Tahunians, show that microlithic-sized implements had a long existence under unfavorable conditions of climate in Palestine.

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[1] Ibid.

[2] Ibid.

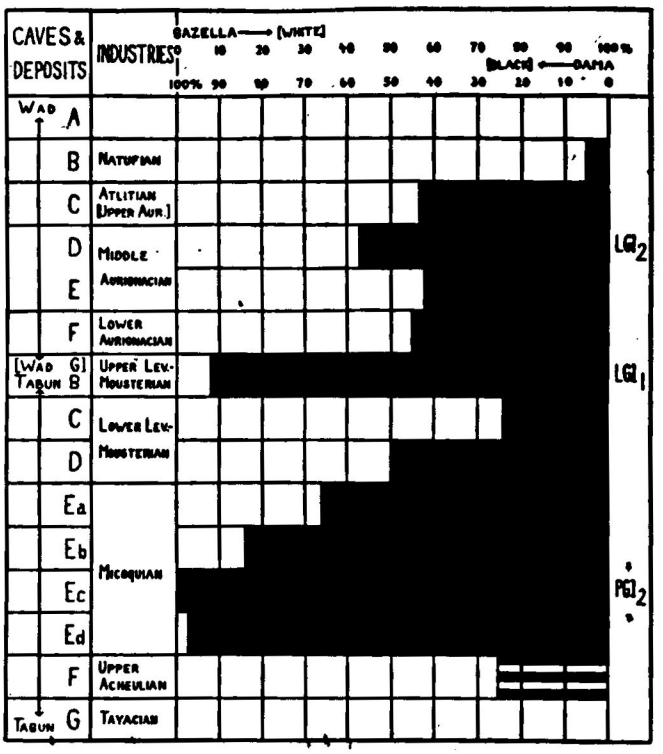

Figure 1.--Ratio between Gazella and Dama Mesopotamica for Each Climatic Phase of the Last Glaciation. Taken from F. E. Zeuner, Dating the Past, modified after Miss Bate in Garrod and Bate, Stone Age of Mount Carmel.

CHAPTER II

PALEONTOLOGICAL INFERENCES ABOUT THE PALESTINIAN CLIMATE

Paleontological methods.--The paleontologist encounters little difficulty in the identification and classification of the general types of faunal remains. Being well enough acquainted with the habits of the most common types of animals and of the conditions under which most animals live, the investigator can form a reasonably clear picture that will shed some light upon the environment and other conditions that existed at the time the animals which are represented by the faunal remains were alive.

Climatologically, the method of procedure consists of the following steps:

(1) Identification of the faunal remains discovered.

(2) Classification of these remains according to the climatic conditions which are best suited to the development and preservation of life of the animals under investigation.

(3) Determination, in a geological sense, of the stratigraphical relationship of the various levels involved at a point of discovery.

(4) Establishment of a numerical tabulation of the total find according to types.

(5) Formation of a timetable for climatic conditions of

the period under discussion.

For paleontological evidence of the climatic conditions of the Palestinian area during the Last Glaciation, we are to rely principally upon the works of D. M. A. Bate of the Royal Anthropological Society of Great Britain. Miss Bate is a paleontologist who has spent many years working in the Eastern Mediterranean area, and as a result has uncovered much valuable information that helps to establish the probable climatic chronology in that area for the Last Glaciation.[1]

After having carried out several investigations over a number of years, Miss Bate decided that two general types of deer, the faunal remains of which were well represented over a long period of time, could be safely used as an indicator of climate for a great part of the Upper Pleistocene:

(1) The Gazella, which was a dry climate animal that roamed the open fields or plateaux.

(2) The Dama Mesopotamica, which was acclimatized to damp places and inhabited swamps or forests where a plentiful water supply was available.[2]

The faunal evidence for the early phases of the Last Glaciation as based upon the Gazella-Dama sequence is presented in much the same manner as the archeological material, in stratigraphical succession, beginning at Tabun C and D and continuing

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[1]Garrod and Bate, op. cit., pp. 139-156.

[2]Ibid., pp. 141-142.

through to the end of Wad C, at which time new species are encountered and dealt with.

Stratigraphical Succession of the Dama-Gazella Remains

Climatic Inferences

Lower Levalloiso-Mousterian: Tabun D and C.--These two levels present evidence that shows that considerable climatic changes were taking place. This is shown by the elimination of some species of animals and a change in proportional numbers of some others. This is particularly true in the case of the Dama and the Gazella. In level D of Tabun the numbers of the two types are about equal, whereas, immediately prior to this level, in E of Tabun, Dama greatly outnumber Gazella. This indicates that the climate was getting drier after level E of Tabun and continued so until the height of level D. This dry condition lasted until the end of level C, at which time the rainfall increased and continued moderately heavy throughout the levels of Tabun B and Wad G. It is at this stage that the great faunal break, from old to modern types of animals, gives a degree of validity to the contention that this pluvial period corresponds with the first phase of the Last Glaciation.[1]

The hippopotamus and rhinoceros, animal types that thrived in a hot climate with an abundant rainfall, are not seen in Tabun B, nor in any later levels. Some of the new types discovered in Tabun B are the hedgehog, pig, hare, and the wolf.

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[1]Figure 1, Wad G and Tabun B, p. 15.

This change in animal types is associated with a change in climate. The increase in rainfall was accompanied by a general lowering of the temperature, though there is not evidence that the climate became cold at that time. The faunal remains in Tabun B are climatically correlated with the first phase of the Last Glaciation, at which time the break from old to modern types of animals occurred.

Chatelperronian--Wad F.--The faunal assemblage of this level is of modern type and, as a whole, indicates that much drier climatic conditions prevailed than during Wad G and Tabun B. The increase of the Gazella at the expense of the Dama shows that the climate changed from a moist to a more arid condition.

Aurignacian--Wad E and D.--The climatic conditions that prevailed during Wad F remained much the same throughout the level of Wad E. The numerical relationship between the Dama and the Gazella was about equal throughout the two levels. This indicates that there were no great climatic changes.

In Wad D, the situation became different again. The increase of Dama at the expense of Gazella suggests that an increase in precipitation followed at the end of Wad E.[1]

Atlitian--Wad C.--At this level there developed an increase in the number of Gazella and a decrease in the number of Dama. The change of climate was of a minor nature and did not differ much from the conditions that prevailed in level D. The tendency was from a damp phase to a more arid condition.

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[1]Frederick E. Zeuner, Dating the Past (London, 1946), p. 229.

Natufian--Wad B.--It is at this stage in the faunal succession that a haze of obscurity beclouds the exact position of the Natufians in the Palestinian chronology and, to a great extent, the climatic conditions that developed after them. The climate is known to have become hot and dry during the time the Natufians were in Palestine. Miss Bate has uncovered some new evidence which she thinks indicates that there was a climatic change subsequnt to the time the Natufians were in Palestine.[1] She bases her opinion on the fact that in level B of Wad, level B of Kebara, level B of Wad Shukba and at a few lesser sites, faunal remains of new types of animals were found in association with Natufian archeological material. Since remains of those animals are not found in the earlier levels of the Palestinian succession (except in a few isolated cases), and since they are different from the species that are found in Palestine today, Miss Bate classifies them as new species and describes them in the following manner:

(A) Gazella Decora--Physical Features.--The skull of the Decora was much larger than the present day Gazella of Palestine. This was also true as to the horns and brain case.

Location.--This species was found at Wad B, B_2 and B of Shukba, and B of Kebara. It is associated with Natufian and with Kebaran. Decora was the dominant species in the Mesolithic levels of the Mughara region, and is not found any

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[1]D. M. A. Bate, "The Fossil Antelopes of Palestine with Descriptions of New Species," The Geological Magazine, LXXVII (1940), 418-443.

earlier than the Kebaran. This suggests that it arrived late in this region.[1]

(B) Gazella Esdraelonia--Physical Features.--This species was about the same size as the Recent Granti Gazella and was smaller than the Decora.

Location.--It was located in Palestine and is associated with a Kebaran industry which is said to be Mesolithic but earlier than Natufian of Wady el Mughara. It is included in the same group as Decora.

(C) Gazella Arista--Physical Features.--This species was of fairly large size, probably somewhat larger than Gazella Decora. The horns were close together and rather short.

Location.--This genus was found in the Wady el Mughara caves and the Judean Hills and at Shukba. It was obtained from levels E and C of Wad (Aurignacian and Atlitian respectively--the isolated cases), B of Wad, B of Shukba, and B of Kebara. These last three levels indicate that the species, although living during the Aurignacian period, were well represented among the fauna that lived during the Natufian epoch.

(D) Genus Robies.--This genus is not well represented. It is found in Wad B, and according to Miss Bate's quotation of Theodore Roosevelt, "They were found on the immense dry flats, sometimes among the scattered thorn trees, sometimes out on the stretches of short grass. Although in the neighborhood of water they sought merely to drink, they were grazers like the

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[1]Ibid., p. 422.

rest of the genus."[1]

These new discoveries suggest that, subsequent to the great faunal break during the first phase of the Last Glaciation, there was another temporary change in climate at which time these new species of animals came into existence. Miss Bate thinks that the "increase in number of extinct species of the Mesolithic period further emphasizes the difference from the recent species in the country. This is unique of Palestine and of the Mediterranean area. In northwest Europe only one of two extinct species occur."[2]

Among the species which need open country and dry conditions were the antelopes, wild goat, large horse and the rodent mole. Gazellas were the most plentiful of the remains found, nearly two thousand to eighty for the next highest number. It is on the preponderant numerical superiority of these dry climate species that Miss Bate bases her dry spell for Palestine during the Natufian epoch.[3]

The establishment of a dry spell for the Natufian levels agrees with the climatic chronology of Palestine that has been established on geological, archeological and astronomical bases. Subsequent to the Natufian period, no evidence has been found of the dry climate species that are known to have lived in Palestine during the time the Natufians were there. Miss Bate thinks that the disappearance of the species was caused or influenced by a change in the nature of the climate.

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[1] Ibid., p. 436.

[2] Ibid., p. 437.

[3] Ibid., p. 441.

If a change of climate did occur at this time, it could have been only an increase in precipitation because during the life of the species under discussion, the climate was dry. The writer thinks that if a wet phase did occur, it should be correlated with the third glacial maximum because the Natufians were in Palestine during all of the second glacial minimum, all of which time the climate was dry. Possibly the Natufians stayed there until well into the third glacial maximum. It must be remembered that some animals were able to adjust themselves to various types of environment and, therefore, may have become tolerant of widely different conditions. To base the occurrence of a wet phase upon the disappearance of a dry climate species may not be safe even though other inconclusive evidence in support of the increase of precipitation at this stage is brought forward.

Zeuner, however, expresses the opinion that there is no evidence to prove that the third phase of the Last Glaciation caused a great change in the condition of climate in Palestine.[1]

The two contrasting opinions expressed by Miss Bate and Zeuner differ only on the probability of a belated wet phase and its place in the climatic chronology of Palestine. There is perfect agreement that the second glacial minimum phase was hot and dry. Whether or not a wet phase did occur at this juncture is entirely open to speculation. The present available evidence does not prove it. The disappearance of dry climate species, and the absence of evidence as to what, if any, people

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[1]Zeuner, op. cit., p. 229.

succeeded the Natufians are due to causes that are unknown to us.

CHAPTER III

GEOLOGICAL EVIDENCE OF PALESTINIAN CLIMATE DURING THE PLEISTOCENE

Introduction.--The interpretation of geological evidence and the application of geological principles in any locality must be done with caution. At best such evidence is speculative and, in the absence of other substantial evidence, should not be accepted as infallible.

The interpretation and evaluation of the available geological evidence within the Palestinian area during the Pleistocene is based upon the works of Leo Picard, who, having carried out extensive geological investigations within the region, found evidence of two pluvials for the Pleistocene period. It is from his most recent available investigation that information for this chapter is obtained.[1]

Even though the scope of this thesis covers only the last 115,000 years of the Pleistocene period, the geological evidence for the whole of the Pleistocene, which covered a period of from 600,000 to 1,000,000 years, is given in order that the history of the climate as based on geological evidence for Palestine may be the clearer, and more particularly to determine whether one or both of Picard's pluvials belong in the Last Glaciation

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[1]Leo Picard, Structure and Evolution of Palestine (Jerusalem, 1943), p. 89.

(115,000 years). The investigation was begun in the coastal plain where an abundance of marine sediments was uncovered and examined in the more recent levels which were found on the seaward side of the coast. The continental sediments were found in the central and eastern sections of the plain.

After taking notice of the evidence of evolution (faulting and regression) in this area, the investigation was moved to the mountain and intermountain regions. By spreading out over widely separated areas in this manner, a reliable geological interpretation of the sediments was made.

From these scattered sources a geological interpretation of the history of the climate within the Palestinian area for the Upper Pleistocene period is to be developed.

Marine Quaternary of the Coastal Plain

A great part of quaternary (the period of the formation of rocks; equivalent to the Pleistocene and Holocene combined) formation of the coastal plain consists of a hardened calcareous sandstone which is known as kurka. This material is produced by two widely different methods between which it is difficult to distinguish, according to Picard. The first method by which kurka is produced is by the accumulation of sand dunes which are allowed to exist over a long period of time. The second method by which it is produced is by the accumulation and prolonged existence of genuine marine sands.[1] Picard thinks that

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[1] Ibid.

where marine mollusca exist in heavy concentration such kurka is "marine in nature and in origin."[1] Geologically, such an hypothesis appears reasonable since marine mollusca cannot live in a dry, arid climate.

In the eastern coastal plain, quaternary marine sediments could not be found except as out-crops in the foothills or near the border of the mountains. In the northern coastal plain, terrestrial kurka (which is dry kurka formed by the weathering of continental drift) is found resting upon chalk and flint.

The two sections into which the northern coastal plain is divided indicate that the area was once a bay. The indication is induced by the presence of dune regions in the western part of the northern coastal plain, and the presence of the blue grey and dark grey clay in the eastern part of the northern coastal plain.[2] The dunes were formed by the action of the wind, and the clay by the action of the lake upon the bed upon which it rested.

A marine complex was also traceable in the northern coastal plain. This complex was a horizon with an overlay of recent sand dunes, which consists mainly of clay and argillaceous sand that extends from about sea level to a depth of about 45 meters below sea level.

Below this occur other formations such as kurka and red loamy sand with characteristics of an eluvial soil that is also

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[1] Ibid.

[2] Ibid., p. 92.

found in the southern coastal plain. All of these soils are at least from 45 to 95 meters below sea level.[1] There follows another marine horizon between 95 and 105 meters. This horizon is then followed by an indefinite type of kurka which is from 105 to about 120 meters below sea level.[2] It appears, then, that successive marine transgressions have occasionally been replaced by land sediments such as limestone, sand, and an odd type of kurka. Picard identifies the younger marine transgression (35 to 45 below sea level) with the Mediterranean sea level and correlates it with the Middle Pleistocene. He also thinks that the dunes might "well have developed as late as the Upper Pleistocene."[3]

For the coastal plain, the following summary may be made: (1) The Lower Pleistocene is mainly represented by continental deposits, with land sediments being deposited in the Haifa Bay region where smaller fluctuations carried the sea occasionally to the westernmost mountain ridges. (2) The Middle Pleistocene is distinguished by a well defined transgression in both the northern coastal and the central coastal region, but it reaches the vicinity of the mountains only in the Haifa Plain; in the central coastal plain it does not extend beyond the middle of the plain; in the southern coastal plain, there is not sufficient evidence that the younger transgression was formed during the Middle Pleistocene period. It is possible that

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[1] Ibid.

[2] Ibid.

[3] Ibid., p. 93.

volcanic behavior could partially account for stratification of the marine and non-marine elements described above, though Picard does not think that tectonic movements occurred in sufficient force to influence the order of stratification during the Middle Pleistocene.[1]

The Continental Quaternary of the Coast

Gravels of the Pleistocene were found where the rivers entered the coastal plain. These gravels were sometimes covered with loam, sands, and loess. They were found in deep cuttings (degradation) or by borings made in the coastal plain.[2] In the mountains they were found 50 to 100 meters above sea level; in the center of the plain they were found at sea level. This order of incidence indicates that flood plains, or rivers emptying into lakes or pools, abounded in the center of the plain at that time. This phase of gravelling dominates the greater part of the Lower Pleistocene. The coastal plain gravels were covered by terrestrial formations which are older than the marine sediments of the Middle Pleistocene (which are 35 meters below sea level). A second higher gravel strain is attributed to the Middle Pleistocene. It is a thin layer traceable in the western part of the coastal plain. In the Haifa Plain there is a difference of 30 meters, from 10 to 40 meters below sea level, between the lower and higher horizons of the terrestrial gravels. At another place in the same area, there

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[1] Ibid.

is a difference of only a few meters. Such inconsistencies make it difficult to label one horizon Lower Pleistocene and the other Upper Pleistocene. The absence of gravel transgressions in the inner plain and the existence of gravelling in the center or middle of the plain indicate that if any tectonic movements took place at that time, the evidence of them is to be found at the eastern terminus of the Mediterranean Sea.[1]

Kurka

Generally, the formation of kurka is a continental process, even though the sediment may be marine in origin. Picard thinks that the quaternary kurka at the present time is mainly distributed in the western half of the coastal plain.[2] Kurka here is divided into two complexes (upper and lower complexes): (1) The lower is often subdivided by eluvial horizons; red sands, clay sands, and loams. In some other areas of the plain (Tel Aviv and the sourrounding area) the lower kurka is replaced by a dark marsh soil (Dark Hamra), red sands and fluvistile pebbles. In the Gaza neighborhood, where Middle Pleistocene marine transgressions seem to be lacking, the kurka also represents the Middle Pleistocene and ranges from 40 to 50 meters above sea level. (2) The upper horizon rests upon the marine deposits and is usually found from Mediterranean sea level upwards.

Continental Evolution

After faulting and regression in the Lower Pleistocene,

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[1] Ibid.

[2] Ibid.

which could have influenced the formation of transgressions at that time, there followed between Lower and Middle Pleistocene a series of uplifts and regressions. Picard expresses the opinion that the intensity of uplifts and regressions was rather slight as evidenced by the formation of dunes which were in turn transformed into the lower kurka complex.[1] Renewed subsidence is represented by distinct fluctuating Middle Pleistocene transgressions, which Picard provisionally terms a "Mediterranean Sea Level Horizon."[2] Further regressions and uplifts are recorded from Middle Mousterian up to the Mesolithic (roughly 130,000 to 15,000 years ago).[3] These developments lead again to dune formations and finally to the upper kurka complex which, in the central coastal plain, was distinguished by a linear arrangement of the kurka ridges. Picard attributes the successive formations of the kurka complexes to periodic tectonic movements of faulting followed by periods of stability and then subsequent regression.[4]

Red Sands and Loams.--The red sand found in the region was subjected to Mediterranean weathering. Loam was located in the eastern end of the red sand belt. These two types of soil were found just over genuine gravel facies. This indicated that prior to the development of the loamy sand, a plentiful supply of precipitation was available. It was when the lakes and

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[1] Ibid., p. 97.

[2] Ibid.

[3] Ibid., pp. 98-99.

[4] Ibid., pp. 99-100.

ponds, which were formed when the water supply was sufficient, had begun to disappear that the formation of these soils took place.[1] Hence, the formation of these soils occurred during a continuous decrease in the amount of precipitation and the water supply.

The Mountain and Intermountain Quaternary

The information for the mountain and intermountain depressions is based mainly upon a study of the deposits uncovered in the Jordan Valley. It is in this valley that the most systematic geological research has been carried out. According to Picard, "the intermountain depressions were filled by 'huge masses' of gravel and pebbles of Diluvial Age."[2] The fluvial materials, which are considered to belong to the Lower Pleistocene, were found at a depth of 400 meters below sea level.[3]

The formation of calcareous rocks from red sand in the Northern Jordan Valley, and the formation of surface crust, or "Nari," by the exposure of the top soil to Mediterranean weathering in the Southern Jordan Valley, indicate that there was a continued climatic change from the heavy pluvials during the Lower Pleistocene, when the pebbles were formed under diluvial conditions, to drier and less moist conditions during the late Lower Pleistocene or early Middle Pleistocene when the formations of the limestone rocks and surface crust were completed. In the Southern Jordan Valley, where aggradation instead of degra-

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[1] Ibid., pp. 99-100.

[2] Ibid., p. 103.

[3] Ibid.

dation took place, the brown surface crust was widespread and was found as far as the Judean Desert. The formation of the surface crust and of limestone rock from red sands cannot take place under heavy pluvial conditions. The subterranean carse not only indicates a change from a very moist to a dry climatic condition, but is also evidence of the fact that the general area was often inhabited from as early as the Acheulian up to the Mesolithic period (from about 160,000 to 15,000 years ago).

Therefore for the quaternary of the mountains and intermountain regions there was a period of heavy and prolonged pluvials during the Lower Pleistocene as evidenced by the accumulation of gravels and pebbles, and during the late Middle and early Upper Pleistocene there developed a more arid condition with intermittent damp phases as evidenced by the formation of the "Nari" crust and limestone rocks.

Quaternary of the Jordan Graben

Lower Pleistocene--Samrar State.--In this area we are to examine erosion and accumulation, and subsidence and uplift as well as fracturing and volcanic action. The geological evidence of the quaternary shows that uplift and downfalling of the mountain and Graben respectively occurred during the transition from the tertiary to the quaternary.[1] There is also evidence of further uplift and downfalling occurring subsequent

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[1]The tertiary is a geological period of time in which geographic changes were wide spread. Chronologically, it immediately precedes the quaternary.

to the transitional period. Picard believes that the height of the mountain at the present time is due entirely to the volcanic and uplifting movements of the quaternary.[1]

Reddish loams and sandy loams intermingled with Naharaim gravels are considered as belonging to an interpluvial phase, and are also considered as deposits of terra-like formations. These loams and deposits of terra-like formations represent halts in the pluvial cycles. This is further indicated by the rivers that flow into the Jordan farther south. The older or Lower Pleistocene is represented by the beds of these rivers, which are hard conglomerations of cement running as high as 40 meters thick, with interminglings of brownish-red terra rosa. The current bedding forced Picard to assume that the material was poured into a body of "standing water" during the Lower Pleistocene in the Jordan depression.[2] If this is true, Pluvial A does not belong to the Last Glaciation but rather to the one that precedes it.

This body of water may be correlated with the development of rivers and lakes during the Lower Pleistocene period. Since Pluvial A is correlated with the development of the lakes and rivers during this period, it also belongs to the Lower Pleistocene. Evidence of the Samrar series (after the namesite, Khirbet Samrar) is more abundantly available in the big quarries which are 6 kilometers northeast of Jericho. There, quarries

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[1] Ibid., p. 107.

[2] Ibid., pp. 108-109.

up to 250 meters in depth are identical with the occurrences of calcareous sandstones and flint collections at Nefi Musa. It is apparent that a great lake, or a series of lakes, prevailed in the Jordan Graben during the Lower Pleistocene into which the rivers poured their material.[1]

Transition from Lower to Middle Pleistocene

Main Interpluvial

The presence of a dislocation (displacement of rock structure by faulting) is the only possible explanation for the difference in height of 165 millimeters between the Samrar series at Khirbet Samrar and those of Nefi Musa near the Dead Sea. The Middle Pleistocene Lisan beds extended to the mountain border and not to the height of the Nefi Musa region. The existence of a definite faulting phase in the interval between the Lower Pleistocene Samrar stage, and before the disposition of the Middle Pleistocene Lisan stage, becomes also apparent from observation farther in the north.

Middle Pleistocene--Lisan Stage.--The slight but distinct discordance between Lower and Middle Pleistocene and the peculiar distribution of sediments from stagnant water at the end of the Lower Pleistocene indicate that there were no tectonic occurrences immediately before the fracturing and volcanic phase set in. With the Middle Pleistocene, a new and very erosive epoch prevailed in the mountains and a new and very accumulative phase began in the depression. These developments

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[1]Ibid., p. 108.

are indications of heavy pluvial conditions and it is because of them that Picard correlates Pluvial B with the latter part of the Middle Pleistocene.

The products of deposition are known as Lisan deposits. One usually understands from this name the thin laminated marl and gypsum beds which were so well developed in the Jordan Basin. The fluvial facies of the Middle Pleistocene were represented by alluvial cones up to 60 millimeters in thickness which were composed almost entirely of pebbles and coarse sand. The Middle Pleistocene alluvial cones stand out most strikingly in the area where the rivers flow into the Dead Sea.

The elastic material of the Middle Pleistocene corresponds with the formations still exposed in the adjoining mountains. The fluvial series are loose formations and, in contrast to those of the Lower Pleistocene, are not solidified. Much basaltic material is found in the Middle Pleistocene.

At the end of the Middle Pleistocene Lisan period, the Lisan series were covering the Jordan Basin right up to the mountain and were extending from the Northern Jordan Valley to the Dead Sea.

Upper Pleistocene.--It was after the Middle Pleistocene that the inland Jordan Lake was dried out. The Jordan and its tributaries dug their beds into the inland (Lisan) sediment.

This inland lake, in the process of drying up, gradually formed numerous terraces. The oldest and highest terraces are found on the mountain border at Jericho. From the mountain at Jericho to the Dead Sea there is an irregular plain of falls from

200 meters above to 350 meters below Mediterranean Sea level. Picard found evidence of several (3-4) terraces which in many places had been worn away.[1]

A brief description of three of these terraces which are found between 200 meters above and 350 meters below the Mediterranean Sea level follows: (1) The highest terrace level, I, is at present 200 meters to 210 meters above Mediterranean Sea level; (2) A well-developed terrace level, II, is at 60 meters to 80 meters above Dead Sea level; (3) Terrace III is 14 meters to 20 meters above Dead Sea level.

Between terraces II and III are 4-6 intermediate stages near the Dead Sea. Few of these are preserved in the plain of the Jordan Valley. Picard thinks that the readily erodent nature of the soil indicates youthfulness of the Jordan and its tributaries. The Jordan appeared only after the drying up of the Lisan beds. The Yamuk, which flowed into the lake of Tiberias, took its present southerly course in the Upper Pleistocene and, at the beginning of the Holocene, developed a broad plain like that of the Jordan.[2]

It was only in the upper half of the Pleistocene that the Jordan drained the lake of Tiberias, bearing off its water to the Dead Sea. This was responsible for the presence of the "intermediate and dry" lakes which have already been discussed.

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[1] Ibid., pp. 108-110.

[2] Ibid.

Summary

The Lower Pleistocene--Pluvial A.--The Graben was covered by a fresh-water lake or by a series of such lakes (Samrar Stage). (Enormous amounts of gravel poured into them from the lateral valleys. It is believed by Picard that the Huleh, Tiberias and the northern end of what is now the Dead Sea belonged to this lake.)[1]

This was not an inland lake, and therefore an arid climate is not indicated. It is thought that Mediterranean climatic conditions prevailed even in the southern valley.[2]

Middle Pleistocene B.--Tectonic movements and volcanic action took place between Lower and Middle Pleistocene. These developments changed the altitudes of the relief. During the latter part of the Middle Pleistocene the fresh-water lake of the Lower Pleistocene was dried up in the Southern Jordan Valley. The Huleh Basin became eluvial from the Central and Northern Jordan Valley by the formation of a basalt-barrier. The present formation of the Dead Sea was laid down at that time by faults of flexure that occurred as a result of tectonis movements.

The degradation of numerous rivers deposited sediments in the deeper part of the basin under the influence of an arid climate. These deposits were thicker in the Dead Sea region than they were in the Northern Jordan Valley.

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[1] Ibid., pp. 114-116.

[2] Ibid., pp. 116-118.

Upper Pleistocene.--At the beginning of the Upper Pleistocene, the winter rains decreased in quantity. The arid condition was then set for the present arrangement of the Jordan River. After the drying up of the Middle Pleistocene lake, strong erosions set in during the Upper Pleistocene. This is when the Jordan cut through the basalt-barrier between the Huleh and Tiberias lakes. The Jordan rapidly gnawed its way into the Lisan layers, which were soft and flexy, and carried its sediments into what is now the Dead Sea. The depositing in this region of these sediments, which are of Jordan origin, was accompanied by tectonic movements.

The evidence herein suggests this climatic analysis: (1) If there was a pluvial phase in the Upper Pleistocene, it was mild and much less intense than the two preceding pluvial phases, A and B. (2) Geological evidence has not been found to indicate that there were heavy pluvials for the second and third phases of the Last Glaciation. (3) The absence of geological evidence of pluvials does not preclude rainfall. (4) The period of heavy pluvials which has been established for the Middle Pleistocene (pluvial B) belongs to the first phase of the Last Glaciation.

CHAPTER IV

THE ATSRONOMICAL THEORY AND ITS APPLICATION TO PALESTINE

Introduction.--The information used in this study of the effects of the movements of some of the planets upon the behavior of the earth as it revolves around the sun is based upon the works of Frederick E. Zeuner who has examined and taken into account most of the leading authorities on the subject of the influence of sun radiation upon the earth. Zeuner uses particularly the works of M. Milankovitch whose latest technical study and evaluation have been further explained and presented by Zeuner in his application of the theory to particular regions.[1]

The Theory.--The theory attributes the variations in the amount of radiation received by the earth to the periodic infractions, or irregular movements, that the earth undergoes as it revolves on its axis and travels in its orbit. These movements (hereafter called perturbations) are three in number and are assumed themselves to have exhibited regular rhythmic movements which can be calculated mathematically. The regular movements of the perturbations produce irregularities in the major movements of the earth. A brief description of each follows:

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[1]*Op. cit.*, pp. 263-268.

1. The first perturbation is the obliquity, or angle, that is formed by the tendency of the earth to vary its equatorial plane with the plane of its orbit as it travels around the sun. This angle is known to have varied between 21° 39' and 24° 26'. A decrease in the obliquity diminishes the difference in the amount of radiation received during the seasons. At the same time it increases the difference in the amount of radiation received in the different climatic zones. An increase in the obliquity increases the difference in the amount of radiation received during the seasons and diminishes the difference between climatic zones.
2. The second perturbation is incidental to the fact that as the earth travels in its orbit there is a time when it is nearer to the sun than at any other time during the year. The perturbation consists in the variations of this distance from year to year, and over a long period of time it causes a difference in the lengths of the seasons. An increase in the eccentricity increases the difference in the lengths of the seasons. The reverse is true of a decrease of the eccentricity.
3. The third perturbation arises in the conical movement of the earth's axis. This perturbation causes a shifting of the seasonal points (spring and autumn equinoxes, and summer and winter solstices), which delimit the seasons.

<u>The Influence of the Combined Actions of the Perturbations</u>.--

The combined actions of the perturbations influence the distribution of the amount of radiation received by any particular part of the earth's surface. If the influence in any particular place is such that the difference between high summer and low winter radiation is increased beyond what it was before the combined actions of the perturbations occurred, the result is a movement in the direction of a non-glacial type of climate. This is true of the northern zone (55° to 65° north latitude). Further south (25° to 35° north latitude)the climate becomes arid with high temperatures and a minimum of rainfall. If the influence of the perturbations is such that the difference between summer and winter radiations is decreased, the result is a movement in the direction of glacial conditions in the northern zone and towards increased rainfall and heavy pluvials at 25° to 35° north latitude. In the northern latitudes a prolonged period of high winter and low summer radiation causes a steady fall of the snowline in the mountains and the adjacent areas. The fall of the snowline is due to the fact that not enough radiation is received in summer to melt the snow that falls during the winter. Consequently, the development of a glacier, which results from a continuous fall of the snowline, is due to the period of high winter and low summer radiation. Farther south, in the eastern Mediterranean area, which concerns us, the annual average temperature is higher, and there are no high mountain systems as there are in Europe. Thus glacial conditions do not occur. The snowline in the eastern Mediterra-

nean area is higher than any mountain system found there.[1] Therefore, as a result of the combined influence of the perturbations, the rain-bearing west winds that approached Europe and Africa from the Atlantic were forced by the high atmospheric pressure over the ice sheet into lower latitudes where the atmospheric pressure was not as great. As a consequence, the rain-bearing winds deposited their moisture in the southern, eastern, and northern Mediterranean areas during each maximum phase of the Last Glaciation.

During each minimum phase of the Last Glaciation the rain bearing west winds from the Atlantic were not depressed into southern latitudes but took their course across northern Europe and deposited their moisture in northern latitudes. As a consequence, the eastern Mediterranean climate was hot and dry during each glacial minimum phase of the Last Glaciation.

Milankovitch's Method.--Milankovitch added two new points to work previously done on the astronomical theory. First, he arbitrarily divided the year into equal parts which consisted of summer and winter. He arranged this by joining summer and spring to form one half of the year, and by joining winter and autumn to get the other half. By manipulating the seasons in this manner it was possible for Milankovitch to get two half years which could be compared with each other.[2]

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[1]The height of the snowline at the present time at 65° north latitude is 1000 meters above sea level. At 35° north latitude it is approximately 4900 meters above sea level. See Fig. 3, p. 4

[2]Zeuner, op. cit., p. 138.

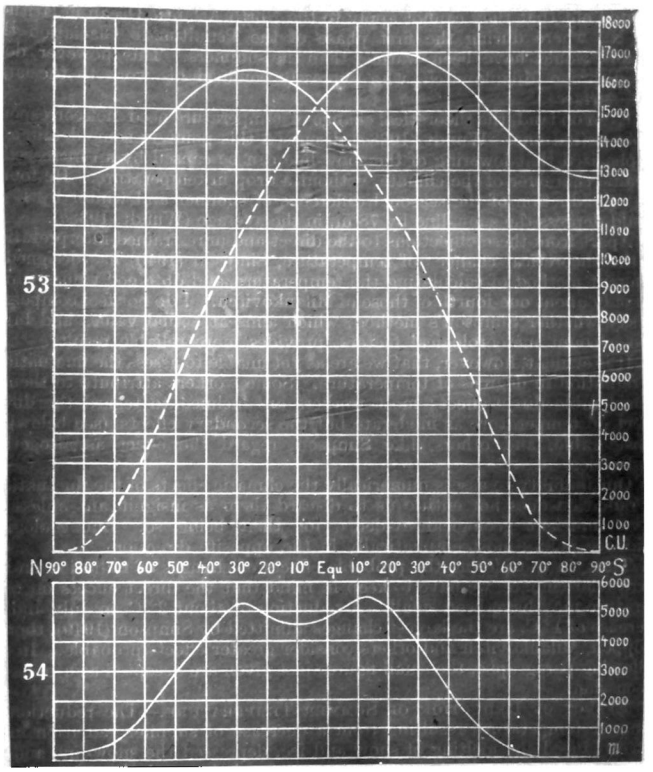

Figure 2.--Present-day summer radiation (full line) and winter radiation (broken line) for every tenth degree of latitude, expressed in canonic units. Taken from Zeuner, Dating the Past. Calculated by M. Milankovitch.

Figure 3.--Present day snow line, in meters above sea level, for every degree of latitude. From Zeuner, Dating the Past. Modified after Köppen and M. Milankovitch.

Secondly, Milankovitch constructed a graph of radiation curves that show the approximate variations in the amount of radiation received by the earth from the sun for every tenth degree of latitude for the last 100,000 years. The graph is divided into units which are called canonic units, and are obtained by substituting one for the value of the solar constant (the annual average amount of radiation the earth receives from the sun), and 100,000 for the sidereal year.[1] The validity of the graph is established by collecting all of the available data on and calculating the regular mathematical factor in the perturbations.[2]

The Application of the Theory to Palestine

For Palestine (whose extremes are approximately 32° 30' to 36° 30' north latitude), 35° north latitude is used as a median reading point. The graph gives the mathematical history of summer and winter radiation for the last c.130 thousand years, and even though our investigation begins at c.115 thousand years ago, the writer will begin at the outer limit of the chart, c.130 thousand years ago, and list and describe each climatic phase at 35° north latitude up to the third phase of the Last Glaciation.

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[1]The sidereal year is the length of time it takes the sun to travel from the fixed position of one star and back to it again.

[2]See Figure 4, p. 46.

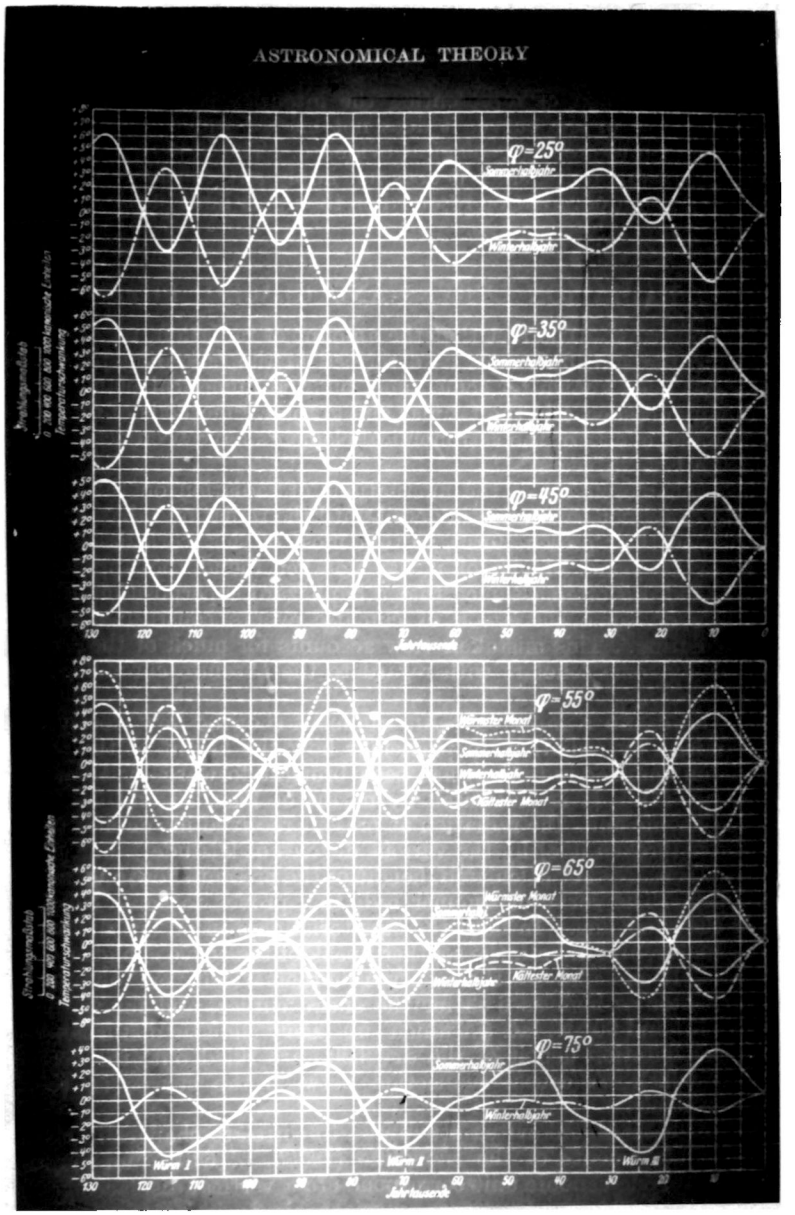

Figure 4.--Summer and winter radiation for the last 130 thousand years for latitudes 25° to 75° N. Summer half-year, full line; winter half-year, broken line. Deviation from the present given in degrees centigrade, scale in canonic units added. Taken from Zeuner, Dating the Past. After M. Milankovitch.

The First phase, c.115 thousand years ago.--Using the vertical scale for 35° north latitude and allowing 200 canonic units for each degree centigrade, we find that at c.130 thousand years ago there was a seasonal difference of 10.2° with summer radiation at +5.1° centigrade and winter radiation at -5.1° centigrade.[1] This means that there was a difference of 2040 canonic units between a summer of high radiation and a winter of low radiation. This seasonal difference was conducive to the development and persistence of a dry and non-glacial climate because what little precipitation accumulated during the winter evaporated during the hot summer months, and most of it was, in any case, carried farther north by the oceanic winds from the Atlantic.

At this stage the interglacial period which preceded the first phase of the Last Glaciation was nearing its end. A gradual decline of seasonal differences set in and continued until about 120 thousand years ago, at which time the amount of radiation received in winter was nearly equal to the amount received in summer. It was then that the last interglacial period had reached its end. The e qual distribution of radiation over the year is associated with the development of a normal or temperate climate.

At c. 115 thousand years ago, the situation was reversed

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[1]The seasonal differences are relly seasonal deviations from the amount of radiation received in summer and winter at 35° north latitude at the present time. See Figure 2, p. 44.

from what it had been c.15 thousand years before. Winter radiation is recorded at +3.5° centigrade and summer is recorded at -3° centigrade. This is a difference of 1300 canonic units with a winter maximum and a summer minimum of radiation. At 65° north latitude this condition produced a glacier proper. At 35° north, it was the cause of the development of a pluvial condition because the rain clouds were blown south. Since high winter and low summer radiation are indicative of glaciers or pluvials, we say that at 35° north latitude the effects of the first phase of the Last Glaciation brought prolonged and continuous pluvials to the Palestinian area. Accordingly, the first phase began its development at c.120 thousand years ago, reached its maximum at c.115 thousand years ago and began to decline at c.110 thousand years ago.

The First Glacial Minimum.--After the maximum of the first phase was reached there was a continuous rise in the amount of summer radiation and a corresponding decrease in the amount of winter radiation. This tendency reached its climax at c.105 thousand years ago at which time there was a difference of 2000 canonic units between the seasons. Then a decline began which at c.98 thousand years ago was interrupted by a non-persistent damp period which was mild and of a short duration. This was the first phase of the first glacial minimum period which usually is regarded as not being divided into two phases but, because the radiation chart records a short, weak damp phase, this change must be recorded.

The peak of this glacial minimum was reached at c. 85 thou-

sand years ago. At that time there was a great distinction between the seasons with a high amount of summer radiation and a low amount of winter radiation with the seasonal difference being about 2400 canonic units. This means that the climate was hot and dry during the second glacial minimum.

The Second Glacial Maximum.--Approximately 77 thousand years ago, the second phase of the first glacial minimum ended. The amount of radiation at that time was equally distributed between the seasons. From the chart it is seen that this period of equal distribution existed for about a thousand years after the decline of the first glacial minimum period. At c.76 thousand years ago, there commenced a disparity between the amount of radiation received in summer and the amount received in winter, with a decrease in the former and an increase in the latter. This tendency persisted until a difference of approximately 900 canonic units between a low summer and a high winter of radiation was reached at c.72 thousand years ago.

In accordance with the interpretation of high winter and low summer radiation, such a happening marks the occurrence of the second glacial maximum of the Last Glaciation which covered a period of c.8 thousand years. This glacial phase ended c.68 thousand years ago.

At the end of the second glacial maximum of the Last Glaciation there was a reduction of seasonal differences; the radiation received in summer was approximately equal to the amount received in winter. But, as shown throughout the scale of the chart, these intervals of equal distribution do not persist for

long periods of time in any instance, usually a little more or a little less than a thousand years.

The Second Glacial Minimum.--At c.67 thousand years ago, there again developed a period of seasonal difference which shows an increase in the amount of summer radiation received and a decrease in the amount of winter radiation received. This period of high summer and low winter radiation represents the second glacial minimum period with the seasonal difference in radiation received being about 1300 canonic units. This phase covered a much longer period of time than its predecessor. From the point of its beginning to its end the second glacial minimum covered a period of about 40 thousand years; from 67 tousand years to about 27 thousand years ago.

The Third Glacial Maximum of the Last Glaciation.--As shown on the chart, the third phase of the Last Glaciation was weaker and of a shorter duration than the two preceding Glacial maxima. Actually, it was less pronounced than the damp period that divided the two phases of the first glacial minimum period. The seasonal difference from the present time was about 550 canonic units with winter radiation being about 3000 canonic units above what it is at the present time and summer radiation being 250 canonic units below the present amount of summer radiation. This phase covered a period of approximately 6000 years, from c.26,000 years ago to c.20,000 years ago. Such a weak glacial phase as indicated by the chart did not have as great an effect upon climate in Palestine as the two preceding maximum phases.

Summary.--The following climatic conditions for each phase are established by evaluating the deductions made from the interpretation of the radiation curves:

(1) The first phase is shown to be a period of high winter and low summer radiation which produced an adundance of rainfall in the Plestinian area. The climate at this time was favorable to the development of human, animal and plant life.

(2) The first glacial minimum is represented by a period of high summer and low winter radiation. This condition was very briefly interrupted by a shift in summer and winter radiation with winter radiation becoming higher than the amount received in summer. The result of this was the appearance of a short and non-persistent damp phase which was immediately followed by the other half of the first glacial minimum. In due course, a gradual decline of the glacial minimum led to a period of equal seasonal distribution.

(3) The second glacial maximum of the Last Glaciation commenced as the period of equal seasonal distribution was followed by a phase of low summer and high winter radiation. The conditions during this phase were of the same kind, but not as intense, as those that prevailed during the first phase of the Last Glaciation.

(4) The second glacial minimum period was not as pronounced or intense as the preceding glacial minimum period, but was of a much longer duration. Nevertheless, it

would seem, from the smaller difference in the amount of summer and winter radiation received, that this glacial minimum would be more conducive to animal and plant life than was the first glacial minimum period because the smaller difference of seasonal radiation indicates that less arid conditions prevailed in the second than in the first minimum phase.

(5) The astronomical evidence indicates that the third glacial maximum phase of the Last Glaciation was not as intense and did not last as long as either of the preceding two maximum phases. This means that the effects of the third glacial maximum had much less influence upon climate in Palestine than the first and second maximum phases.

CHAPTER V

THE CORRELATION OF EVIDENCES

The first Glacial Phase.--The evidence for the establishment of pluvial phases for Palestine during the Last Glaciation is based mainly upon paleontological and astronomical grounds. Though the geological evidence supports the climate chronology in a general way, it does not fit so easily into the history of Palestinian climate for the period under discussion. In correlating the geological evidence with the astronomical and faunal evidences, we are to accept Picard's correlation of Pluvial A because it is outside of the period covered by this investigation.

Picard correlates Pluvial A with the Rissian Glaciation, which began its development about 300 thousand years ago and was followed by an interglacial at about 180 thousand years ago. This interglacial period lasted about 65 thousand years and was then followed by the first phase of the Last Glaciation.

Picard also correlates the development of the Lisan Marls with the interglacial period between Pluvial A and Pluvial B. This means that this interpluvial is to be correlated with the Last Interglacial. Then Pluvial B most likely should be correlated with the first phase (and possibly with the second phase, though there is not enough evidence to prove it) of the Last Glaciation. The astronomical and faunal evidences indicate that

Pluvial B belongs to the first phase.

The radiation curve shows a seasonal difference of 1300 canonic units during the first phase of the Last Glaciation. The ratio of Gazella to Dama is about 1 to 9. These two evidences indicate the heaviest amount of rainfall in Palestine during the entire history of the Last Glaciation. Since Picard was able to find substantial geological evidence only for one heavy pluvial subsequent to the interpluvial period, it would seem that Pluvial B is correctly limited to the first phase of the Last Glaciation.

The First Glacial Minimum.--There is complete agreement among the three kinds of evidence that the climate in the early part of the first glacial minimum period was becoming drier. The gradual increase in the amount of summer radiation and the general increase of the Gazella at the expense of the Dama indicate that there was a general decrease in the annual amount of precipitation. The geological evidence indicates a continual development of arid conditions, punctuated by periodic rainfall throughout the remainder of the period under discussion with a possible minor pluvial at its end.

At the height of the first glacial minimum period the astronomical evidence records a weak, damp phase, the establishment of which is substantiated in a general way by the geological material, but it is not in agreement with the faunal evidence. A minor difference of this sort may be expected in the correlation of evidences which have been uncovered by such widely

different methods. A short damp phase is not likely to have had enough influence upon animal life to have caused any changes in types. For the remainder of the first glacial minimum period there is complete harmony between faunal and astronomical evidences. The geological evidence is not as specific as the other two kinds, but it is indicative of a dry condition throughout the first glacial minimum period.

The Second Glacial phase.--The postulation of the second phase in climate chronology for Palestine is based mainly upon the astronomical and faunal evidences. It can only be surmised whether or not one of the periods of increased rainfall which is based upon the geological evidence corresponds with the second phase of the Last Glaciation. The radiation curve shows that at that time there was a minimum of summer radiation and a greater amount of radiation during the winter. The faunal evidence shows that the dry weather Gazella was decreasing in numbers, while there was a general increase in the number of Dama Mespotamica. During this phase there was a seasonal difference of 900 canonic units. From the astronomical evidence it is seen that precipitation for the second phase was neither as heavy nor as persistent as it was in the first phase. This is further substantiated by the faunal evidence. The chart shows that the ratio between the Gazella and Dama was 1 to 9 during the first phase of the Last Glaciation. This is indicative of a very heavy and prolonged period of precipitation. At the height of the second phase of the Last Glaciation the ratio between the Gazella and Dama was roughly 4 to 6. By

simple interpretation it is seen that there were four times as many dry weather animals in the second phase as there were in the first phase. Not only does this bear out in a most convincing manner the interpretation of the astronomical evidence that the effects of the second phase of the Last Glaciation were much weaker than those of the first phase in Palestine, but it also partially accounts for Picard's inability to find substantial geological evidence of a third major pluvial. Tectonic movements, which caused a disarrangement of the stratigraphical accumulation of land sediments, made it the more difficult to make a clear geological interpretation of the amount of material that was uncovered for this period.

The Second Glacial Minimum.--The astronomical, the faunal, and the geological evidences are in complete accord with the long dry climatic conditions during the second glacial minimum period. There was a seasonal difference of about 1300 canonic units with summer radiation reaching about 700 canonic units above what it is at the present time, and winter radiation falling as much as 600 canonic units below the amount of radiation received in winter at the present time. The Gazella not only greatly outnumbered the Dama at this stage, but continued to increase at the expense of Dama throughout the remainder of the period. Geologically, the shrinkage of the Jordan Lake and the formation of the High Jordan terraces began after the decline of Pluvial B and reached their maximum development during the glacial minimum period.

The Third Glacial phase.--The effects of the third phase of the Last Glaciation were very weak in Palestine. Except for a

weak reading on the radiation curve, there is not much evidence that the climate in Palestine during this phase was much different from that which prevailed there during the second glacial minimum period. There was a seasonal difference of only 550 canonic units. This suggests that the amount of precipitation that occurred during this phase may actually have been less than the amount that occurred during the first glacial minimum period. The faunal evidence indicates dry conditions prior to the third phase, with possibly a minor damp phase occurring either during the third phase or in the immediate post-glacial period. Picard also thinks that the slightly rolled gravels which were found resting on the surface of the high terrace indicated a minor pluvial which he correlates with the transition from the Pleistocene to the Holocene.[1] The writer thinks it is extremely likely, and more logical to assume, that the disappearance of the Natufians with their dry climate species, and the deposition of gravels upon the high terraces, occurred during the third glacial maximum rather than in the immediate post Glacial period. The available evidence, though inadequate, is more suggestive that a minor pluvial, or wet phase, occurred within the limits of the third glacial maximum rather than before or after its development. It is apparent that the third glacial maximum had less effect upon the climate in Palestine than the two preceding maximum phases. Except for a possible small increase in the amount of rainfall, there was not very much difference in cli-

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[1] Op. cit., pp. 118-121.

matic conditions during the third phase and the preceding glacial minimum period.[1]

[1]Zeuner, op. cit., p. 229.

CHAPTER VI

CONCLUSION

The Influence of Climate upon Human Social and Cultural Development

The condition of climate was one of the most important problems that confronted the people who lived in Palestine during the Last Glaciation. Climate, more than any other factor, influenced the course of social and cultural development in Palestine during that phase of human evolution.

The problem with which the cave dwellers were concerned more than any other during the Last Glaciation was the acquisition of an adequate food supply. Being food gatherers and not producers, they were affected by any great change in climate. Early men depended upon animals more than anything else for their supply of food. An adequate supply of animals for human needs depended upon a necessary amount of vegetation. Whether or not a sufficiant supply of vegetation was available depended entirely upon the condition of climate.

In Palestine during the Last Glaciation, an adequate amount of precipitation was conducive to the growth of an abundance of vegetation and, consequently, to the production and growth of an adequate supply of animals. An inadequate amount of precipitation had an adverse effect upon the food supply. Prolonged periods of drought and aridity caused the development of an

extreme scarcity of vegetation. As a consequence the animals who depended mostly upon vegetation for their existence migrated to areas where a more abundant supply was available.

The human inhabitants were forced to follow the animals to other areas where climatic conditions were more favorable, or to remain where they were and improve their hunting techniques in order to kill some of the few animals that lived under arid conditions. The difficulty encountered in open, steppe country under arid conditions forced the cave dwellers to follow after the animals during the early phases of the Last Glaciation. In the later phases they changed their habits to some extent and remained in some areas for longer periods of time than they had been accustomed to doing. The tendency to remain in some place for long periods under conditions of climatic stress led to the development of new ideas and activities. This is shown by the occurrence of new and different tools in the upper levels of Palestinian industries. Most of the new tools were invented during the long dry phase of the second glacial minimum. It is apparent, then, that the development and use of new tools became necessary in order to live under adverse conditions which were caused by unfavorable influences of climate.

The influence of climate upon human social and cultural development will be shown by a chronological correlation of changes in the tool making process with changes in the conditions of climate in Palestine during the Last Glaciation. In developing the history of cultural progress for the Last Glaciation in Palestine the writer will point out both the orderly, evolutionary

advancements in the making and use of tools, and the sudden, revolutionary deviations that disrupted the normal accumulative process in cultural development.

The First Maximum Phase.--The Upper Levalloiso-Mousterian industry prevailed in Palestine throughout the length of the first phase of the Last Glaciation. The tools most commonly used in this industry were spears, scrapers, and points. All of these were more highly polished and better worked than their counterparts in the immediately preceding industry (Lower Levalloiso-Mousterian). The favorable climatic conditions during the first phase lessened to a great extent the necessity of prolonged hunting trips. This, of course, did not lessen the interest in the care and development of more effective tools. The knowledge that had been gained in the tool-making process under unfavorable conditions during the phase of the Lower Levalloiso-Mousterian was used and improved upon under favorable conditions during the Upper Levalloiso-Mousterian. This accounts for the highly polished and well worked implements mentioned above. The use of previously gained knowledge during a period of leisure in this way was an advancement in human culture.

The First Glacial mimimum.--As the first maximum phase began to decline, there also occurred a change from a moist towards an arid condition of climate. This change in climate forestalled any further large scale development of tools in the flake tradition. After the great faunal break from the old to the modern type of animals which occurred during the first maximum phase, the flake tradition began to decline. At the begin-

ning of the second glacial minimum, the flake tradition was no longer adequate and was replaced by tools in the blade tradition. Such a sudden break in the cultural pattern from the flake to the blade tradition was a revolutionary change in the accumulative process.

The Blade Tradition.--The blade tradition produced a type of delicate points that were more highly polished, and a collection of blades that were thinner and sharper than any that had been produced in earlier traditions. The Chatelperronian and the Middle Aurignacian are types of tools that were made in the blade tradition during the first glacial minimum period. These tools were designed for hunting in open country with a minimum of fauna. The hot and dry climate was not conducive to the development of an abundant animal and plant life. Not only were longer hunting trips necessary but it had become essential that each attempt to kill an animal be a successful one. Therefore, the delicate Chatelperronian points and the sharp cutting Aurignacian blades indicate that climatic conditions forced the inhabitants to devise new techniques in the food-getting process in order to meet their needs.

The Second Maximum Phase.--The late Middle and Upper Aurignacian cultures prevailed in Palestine during most of the second glacial maximum period. The tools, though different in a few minor respects, were generally of the Aurignacian types described above. A few curved blades and some curved steep scrapers and sickles indicate that some form of vegetation might have been reaped for human purposes. This indication is induced by the

highly polished condition of some of the curved blades. It is possible that the cutting and storing of wild grain in selected places could have been another means of supplementing the meat diet. Climate during the second maximum phase was favorable to the production of an adequate food supply, but early man at this stage apparently had learned that changes were to be expected and, to some extent, planned for.

The Second Glacial Minimum--Natufians.--The Natufian is the most impressive of Microlithic industries uncovered in Palestine. This industry had its beginning in the early part of the second glacial minimum and lasted at least until about the middle of the third maximum phase. The climate was hot and dry during the second glacial period. No other phase of the Last Glaciation presents such a prolonged dry spell. Yet large-scale migration had been continually decreasing since the latter part of the second maximum phase. The tendency to acquire sedentary habits and adapt them to the local environment was progressively becoming the normal reaction of the inhabitants to the periodic changes in the condition of climate.

It was during this phase that the Natufians used all of the accumulated knowledge as a means of raising the cultural process to its highest level of development. They remained in the area under these unfavorable conditions and improved upon the technique of acquiring food and making life possible. The one piece sickle was developed into a more complex instrument with a blade and haft. The sickle definitely was used to gather a portion of the available edible grass and probably some other kind of

vegetation. Under the Natufians, the original crude form of the spear was developed into a delicate complexity of detachable parts with barbs on the points. This means that animals had not only become scarce, but also were more difficult to kill. The barbs on the point of the spear made it difficult for the animal to dislodge the instrument once a good strike had been made. Though the animal may not have died on the spot, the hunter could have followed after it with the reasonable expectation that it would have become exhausted at some place not far removed from the point of contact.

For the first time the bow and arrow were improvised and used as a weapon in the felling of game.[1] This in itself is one of the most remarkable inventions that prehistoric man made. The few available animals had been hunted so persistently that they became extremely wary of the approach of those who pursued them. As a consequence, it became difficult to get close enough to make a successful strike, even with the new type of spear. This condition presented a new problem in the food-getting process. The Natufian hunters solved this problem by devising the arrow and concealing themselves near places where it was natural for the animals to visit. By this means, it was possible to get near enough to make a successful strike without

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[1]No evidence was found of bows that were used with arrows. This indicates that bows were made of perishable material which has not survived the long interval of time since they were used.

frightening the animals away. These progressive innovations in the types of tools were made necessary by the unfavorable climatic conditions that prevailed in the Palestinian area during the second glacial minimum period.

Kebaran.--The Microlithic industry of the Kebarans is also correlated with the second glacial minimum period. Except for the occurrence of some sickle blades that were made of bone, there is nothing to distinguish it from the Natufian industry. Both of these industries reached their highest level of development during the long hot and dry climate of the second glacial minimum period.

The Third Glacial Maximum.--The climate in Palestine during the third glacial maximum was not much different from what it had been during the preceding minimum phase. The slight increase in precipitation made life a little less difficult for the Natufians who were there for a great part of the third maximum phase. Miss Garrod thinks that the Natufians were still in Palestine as late as the sixth millennium.[1] If Miss Garrod is correct in bringing the Natufians down to the sixth millennium, then the Tahunian and Jerichoan industries must have been developed within the last eight thousand years. Garstang has dated the pottery-bearing industry of Jericho as early Neolithic. Miss Garrod also thinks that the Tahunian is the connecting link between the Natufian and the Neolithic industries of Jericho.[2] If these postu-

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[1]Garrod and Bate, op. cit., p. 118.

[2]Ibid.

lations are true, then the transition from cave-dwelling to village life culture in Palestine not only occurred during the phase of the Tahunian, but it is also a development of the post-glacial period. The writer does not believe that the Natufians were in Palestine any later than about the middle of the third glacial maximum. Neither does he believe that the Tahunian is the connective link between the Natufian and the Neolithic.

The transition from cave dwelling to village life culture in Palestine is by no means settled. There has not been enough evidence discovered to establish the time or place of transition. Robert Braidwood believes there is a gap in the upper levels of the archeological succession of Palestinian industries.[1] He thinks that the Tahunian and similar intervening industries are not adequate enough bases upon which to establish the history of the transitional period. Until the gap is filled by the discovery and examination of archeological material which he thinks is still embedded possibly in some undiscovered caves, Braidwood proposes to arrest all of the present explanations concerning the transitional period. This interjection by Braidwood is referred to as the "Gap Theory," and since no substantial evidence has been brought forward to disprove it, the writer thinks that the true history of the transitional period cannot be told at this time. It is entirely possible, however, that it might have occurred in the post-glacial period.

Irrespective of the places or immediate sequence of the

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[1]Robert Braidwood, Prehistoric Men (Chicago, 1948), pp. 89-90.

transitional period, the fact is clear that the evolutionary changes in the tool making process indicate that the inhabitants were continually adjusting themselves to the periodic changes in climate that occurred in Palestine during the Last Glaciation.

The highly polished and well worked scrapers and flaked blades are characteristic of tools that were made under favorable climatic conditions during the early part of the Last Glaciation. Since prolonged hunting trips were not necessary, more time was available for the care and upkeep of tools that were in use. The sharp delicate points and slender blades were developed under unfavorable climatic conditions during the middle part of the period under discussion. The change from favorable to unfavorable climatic conditions caused a decrease in the food supply and, as a consequence, made it necessary to improve upon the types of tools in order to secure an adequate amount of food.

The superior innovations such as the bow and arrow, the spear with barbs, and the sickle are characteristic of tools that were developed under conditions of climatic stress during the later phases of the Last Glaciation. The conditions under which all of these changes in the tool making process were made show that climate was the most important factor involved in this period of human evolution.

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Note to the Bibliography of this Thesis.-- The amount of literature on the subject of the thesis is very small indeed. The candidate has used all the most important items. There are a number of less important review articles, etc., which were not available to him. This cannot have upset the argument of the thesis. The importance of the thesis, which is considerable, is in the successful correlation of the several different classes of evidence.

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